



**HAL**  
open science

## Oxidation in white wine: The point of view of winemakers from areas with different oenological practices

Jérôme Mallard, Dominique Valentin, Jordi Ballester

### ► To cite this version:

Jérôme Mallard, Dominique Valentin, Jordi Ballester. Oxidation in white wine: The point of view of winemakers from areas with different oenological practices. *Food Research International*, 2025, 199, pp.115341. 10.1016/j.foodres.2024.115341 . hal-04819037

**HAL Id: hal-04819037**

**<https://hal.inrae.fr/hal-04819037v1>**

Submitted on 4 Dec 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



# Oxidation in white wine: The point of view of winemakers from areas with different oenological practices

Jérôme Mallard, Dominique Valentin, Jordi Ballester\*

Centre des Sciences du Goût et de l'Alimentation, CNRS, INRAE, UB Institut Agro Dijon, Université Bourgogne Franche-Comté, F-21000 Dijon, France

## ARTICLE INFO

### Keywords:

Wine oxidation  
Mental representation  
Perceptual learning  
Experience  
Production practices

## ABSTRACT

Oxygen is an important parameter in winemaking that can have positive or negative impacts on wine quality. A controlled oxygen management can lead a wine with good potential for ageing to develop an interesting ageing bouquet. On the other hand, when oxygen intake is not well controlled, loss of freshness and fruitiness can occur, and some faulty oxidative notes can appear. Oxidation is thus an ambiguous sensory concept and producers' representation of oxidation in white wine may be very different depending on the oenological practices linked to their geographical areas. The main objective of the present study was to evaluate the effect of oenological practices and environment on wine experts' mental representations of oxidation. Semi-structured interviews were carried out with twenty-six French winemakers, half from Burgundy and half from Jura. The results showed that the winemakers from both regions were quite consensual regarding the sensory dimensions associated with oxidation but there were differences between the two regions in terms of which types of oxidation they considered. The idea of premature oxidation was clearly more salient for the Burgundy respondents than for the Jura ones. Our results stress the context-dependent character of oxidation judgement following wine tasting.

## 1. Introduction

Oxygen plays an essential role in the evolution of wine, from the beginning of winemaking to the moment of tasting the wine. Sensory consequences of oxidation have been the subject of numerous research studies focusing mostly on the link between chemical compounds and sensory profile. For example, it was shown that the oxidation of white wines is characterised by the transformation of aroma compounds, leading to a loss of freshness and fruitiness, and the apparition of oxidised characters, such as “cooked vegetable,” “hay,” “honey-like,” “farm-feed”, “woody-like” and “boiled-potato” (Escudero et al., 2002; Karbowski et al., 2009; Silva Ferreira et al., 2002, 2003).

Controlled oxidation can also lead to the development of positive and complex aromas during relatively long ageing for table wines (Liberatore et al., 2010). Positive oxidative characters can also appear in special wines like *rancio*, Port or flor wines like *Sherry* or *vin jaune* (Martin et al., 1992; Culleré et al., 2007; Milheiro et al., 2020). The aromas of oxidised wines and flor wines result from different mechanisms. The former results from a chemical oxidation post-bottling that can take from a few years to several decades depending on the oxidative stability of the initial wine. Flor wines are the product of a long

biological ageing under a velum of yeast that develops on the surface of the wine in presence of oxygen. This velum, which is not formed by the same yeast strain that carried out the alcoholic fermentation (David-Vaizant and Alexandre, 2018), protects the wine from oxidation allowing a prolonged ageing period without risking negative effects of volatile acidity. The final product is a wine with a pronounced golden colour, typical oxidative aromas like nutty, apples, honey, curry and cooked fruit and less fresh fruit aromas than the initial Savagnin wine. Some of these oxidative aromas are close to those characterising normally oxidised white wines (Ugliano, 2013; Silva Ferreira et al., 2003). Moreover, some of the key aroma compounds are also common, like methional and phenylacetaldehyde (Culleré et al., 2007; Escudero et al., 2000) although the concentrations are higher in flor wines (Culleré et al., 2007) contributing to their typicity along with acetaldehyde and sotolon (Martin et al., 1992). Considering the diversity of oxidative aromas and the ambiguity of their contribution to wine quality, oxidation appears as a multifaceted concept worth studying.

A recent study carried out with wine experts and consumers highlighted the ambivalent perception of oxidative characters leading to either positive or negative feelings (Franco-Luesma et al., 2019). Wines were spiked with three volatile oxidation compounds (acetaldehyde,

\* Corresponding author.

E-mail address: [jordi.ballester@u-bourgogne.fr](mailto:jordi.ballester@u-bourgogne.fr) (J. Ballester).

<https://doi.org/10.1016/j.foodres.2024.115341>

Received 2 August 2023; Received in revised form 6 November 2024; Accepted 13 November 2024

Available online 17 November 2024

0963-9969/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

phenylacetaldehyde and methional) to create different levels of oxidation. Participants were asked to decide whether they would serve the wine to their friends. A heterogeneity of behaviours going from rejection to acceptance was observed in the categorisation of oxidised wines irrespective of the participants' expertise level. According to the authors this heterogeneity could be explained in terms of mental representation: Participants would react based on their conceptualisation of wine oxidation. In the present study we wanted to go one step further and explore wine experts' mental representations of wine oxidation using a psychological approach. According to Parr (2019) "The key philosophical change involved in a psychological approach to understanding wine tasting is a shift in focus from the product, namely wine chemical composition and sensory description, to emphasise the taster and his/her interaction with the wine p 231."

The study of wine experts' mental representations is relatively recent in the scientific literature. Most studies published in the last 20 years suggest that experts developed wine sensory concepts based on grape varieties (Ballester et al., 2008), wine colour (Ballester et al., 2009) or wine origin (Green et al., 2011) through perceptual learning mechanisms. These concepts stored in semantic memory would then be used to guide further wine tastings (see Parr, 2007 for a review on the cognitive processes involved in wine expertise). Recently Honoré-Chedozeau et al. (2017) showed that expert wine representations are flexible enough to adapt to different types of situations and environments. This flexibility allows for the adaptation to potential evolutions of oenological practices and is linked to the experience of wine experts.

Experts' experience is linked both to their practice or occupation and to the area in which they work. For example, Otheguy et al. (2021) showed that wine makers, wine sellers, and wine critics developed different representations of the diversity of wines from the Beaujolais vineyard. Along the same lines, Sáenz-Navajas et al. (2021) highlighted a regional effect on Spanish wine experts' understanding of the green character in red wines. Winemakers from DO Ca Rioja and DO Somontano descriptions of a green wine emphasises much more the taste ("excessive sourness") and trigeminal ("dry" and "astringent") sensory dimension than experts from DO Campo de Borja or DO Ribera del Duero. These differences would be due to distinct technical and sensory experiences acquired by the experts from the different regions.

Based on these considerations, the main objective of the present study was to evaluate the effect of oenological practices and environment on wine experts' mental representations of oxidation. We carried out semi-directed interviews with winemakers from Jura and Burgundy regions. The rationale for comparing these two populations of winemakers is that their oenology practices are quite different especially regarding the production of white wines. Winemaking in Burgundy is quite classical. It is characterised by malolactic fermentation and usually oak or vat ageing to obtain white wines with good potential for ageing. Because of this alleged longevity, one of the main problems with white Burgundies is oxidation and in particular premature oxidation.

White wine production in Jura is more diverse and includes classic dry wine from Chardonnay grapes (the most planted in the Jura region), blends between Chardonnay and flor Savagnin wine (in different proportions depending on the desired style). The most emblematic wine in Jura is the vin jaune, a flor wine made from Savagnin, which is submitted to controlled biological ageing during more than six years. Therefore, Jura winemakers are exposed to a wider variety of levels of oxidative aromas from a young fresh Chardonnay to an aged vin jaune, through all intermediate oxidation levels.

Because of these differences in terms of practice, we expected that winemakers' representation of the concept of oxidation of white wine would differ between regions.

More specifically, we expected experts from Burgundy to associate oxidation to Chardonnay and those from Jura to mainly Savagnin although they also produce Chardonnay wines. To test this first hypothesis, we started the interview with an association task using the term "oxidation in white wine" as a prompt. Then, to evaluate the

flexibility of experts' representations we focused the discussion on Chardonnay. This was done mainly to evaluate how the new cue "oxidation in Chardonnay wine" would be dealt with by experts from Jura: would they occult the Chardonnay cue and focus on the oxidation part of the prompt and thus reveal their "stereotypical representations" or would they generate representational elements closer to those of Burgundy experts? Since most Jura producers also make Chardonnay wines, it is possible that in addition to a representation of Savagnin wines, they also developed a mental representation of Chardonnay wine which may be somewhat linked to oxidation.

Finally in a third step we introduced the idea of premature oxidation, an unwanted ageing affecting young wines after bottling (Gabrielli et al., 2021). This early ageing was first cited in the mid-1990 s and seems to appear sporadically on all kind of dry white wines at the world level (Romanet, 2019) but had a particularly strong impact in white Burgundies (Grangier, 2021) probably due to Burgundians claims concerning the high potential for ageing of their whites. Our goal was not to compare oxidation and premature oxidation but to evaluate how different cues associated with the term oxidation modify the elements of representation provided by experts based on their previous experience with different types of oxidation. Premature oxidation being more frequently reported in Burgundy than in Jura we expected this concept to be completely integrated in the representation of experts from Burgundy whereas it might occur more as peripheral elements for experts from Jura.

## 2. Materials and methods

### 2.1. Participants

Twenty-six winemakers (18 men and 8 women) with an average age of 51 years old (aged between 32 and 72 years old) were interviewed. They were separated into two groups of thirteen participants according to the main place of practice of their professional activity. The first group was composed of winemakers from the Burgundy area and the second one of winemakers from the Jura area. Ages and number of years of experience in the wine industry of Burgundy and Jura expert panels are presented in Table 1. Jura experts tended to be older than Burgundy ones and had significantly more experience in the wine industry. No significant difference was found in terms of years of experience in the study regions (Student *t*-test, alpha = 5 %).

### 2.2. Procedure

All interviews were conducted individually, in French, by the first author. Participants were asked to read an information sheet and sign a consent form. It was mentioned that interviews would be audio recorded and that the tapes would be used only for academic research and guaranteed anonymity of participants. Participants were specified that the interview concerned their own ideas and that there were neither right nor wrong answers. They were informed that the interview involved questions about white wines.

The interview moderator guide included six steps including three steps related to the representation/definition of oxidation and three

**Table 1**  
Mean values for age and years of experience for the Burgundy and Jura producers. Min and Max values are expressed in brackets next to each mean.

Region	Age	Experience in the wine industry	Experience in the region
Burgundy	46.4 (32–61)	22.8 (9–40)	20.5 (2–40)
Jura	54.8 (37–72)	32.5 (13–60)	26.8 (2–60)
Difference (Student test)	$p < 0.05$	$p < 0.05$	$p > 0.05$

steps linked to the origin and temporality of the oxidation. During the whole interview, the experimenter used clarification and reformulation questions to encourage the participants to speak freely and to obtain in-depth information. Only the steps linked to the representation/definition of oxidation are presented in this article.

#### Step 1: White wine oxidation free word association task

First, the experimenter asked participants to indicate all the words that came to their mind when prompted with the words: *terroir*, *minerality* and *oxidation*. Only the word *oxidation* was analysed for this study, the other words were used as warm-up.

#### Step 2: Chardonnay oxidation definition task

The interview continued then with a definition task. Participants received the following instructions: “*Could you tell me how you understand/define the word oxidation when you talk about Chardonnay wines?*”

#### Step 3: Premature oxidation definition task

Finally, the interview was focused on premature oxidation. If participants mentioned the term premature oxidation during the interview, the experimenter asked them to define the premature oxidation. Otherwise, the experimenter introduced the concept of premature oxidation with the following question: “*For some time now, in the wine industry, we have been hearing about premature oxidation, does that mean anything to you?*”

After the interview, the participant completed a questionnaire with demographic questions (gender, age, professional activity, education level) and information about their wine expertise (type of structure and location in which they practise their profession, number of years of experience in the wine industry).

### 2.3. Data analysis

The audio-recorded interviews were fully transcribed. They were then grouped to obtain two corpuses corresponding to each group of wine experts: Burgundy and Jura. Each corpus was divided into three sub-corpuses (one per task) which were analysed separately. A frequency analysis, a co-occurrence analysis and a thematic analysis were carried out on each sub-corpus.

#### 2.3.1. Frequency analysis

The goal of this first analysis was to have a first overview of the six sub-corpuses. It was carried out using the SPAD 9.2 (Coheris, France) text mining procedure. The combined corpuses were lemmatized (i.e., the terms were reduced to their simplest form) and non-informative words or expressions removed. Word counts were then computed for each sub-corpus and represented as word clouds. The words included in each question (e.g. oxidation, white wine for the first task) were removed from the corresponding word clouds. A Correspondence Analysis (CA) was finally performed on the sub-corpus\*word frequency table to visualise the distance between sub-corpuses.

#### 2.3.2. Co-occurrence analysis

The goal of the co-occurrence analysis was to explore the structure of the sub-corpuses. It was carried out using the software IRaMuTeQ (Interface R for Analyses of Multidimensional Texts and Questionnaires), version 0.7 alpha 2 (Ratinaud, 2009), that runs in R software version 3.6.3 for Windows (R: The R Project for Statistical Computing, 2020). The procedure used for preparation of each sub-corpus was similar to that described in Otheguy et al. (2021) and summarised thereafter. After a lemmatization of the text sub-corpus, word segments considered as integral words were attached together (e.g. Côte\_d\_Or, vin\_Bourgogne, oxydation\_ménagée). Each sub-corpus was cleaned by removing adverbs, verbs, prepositive and adverbial phrases to keep only nouns and adjectives as active words. The frequency of citation of each word was calculated. Words not cited at least five times were removed

from the sub-corpus. All uninformative words (e.g. *stuff*, *thing*, *word*, etc.) were also removed. Each sub-corpus was divided into text segments, containing 15 words.

Each cleaned sub-corpus was then submitted to a co-occurrence analysis. This analysis is based on the computation of co-occurrence of words within each segment, which is then translated into a similarity tree. This representation permits us to visualise the proximity and relations among selected words. The size of each word is proportional to its occurrence: The larger the word size, the more the word is cited in the text. Similarly, the branch's thickness is proportional to the strength of the connection between two words: The thicker the branch, the more the words are cited together in the text segments. The length of the branches reflects the consensus among experts: The shorter the link, the more important the agreement between experts. Spatial location of words was computed using the Kamada–Kawai algorithm (Kamada and Kawai, 1989).

#### 2.3.3. Content analysis

A thematic analysis was carried out independently by two investigators. First, the two investigators read the transcripts and identified the main themes used by each group of experts. Then, they compared their analyses to obtain a list of common themes for each group of experts. When a disagreement was observed, they discussed to seek a consensus. Finally, they selected the most representative verbatims of each theme.

## 3. Results

### 3.1. Frequency analysis

To have a first idea of the vocabulary generated in the three tasks by the two groups of experts we carried out a frequency analysis of the cleaned corpuses and represented the results as word clouds (Supplementary material). In total, 2253 terms were retained after the cleaning step, 58.3 % of them being generated by the winemakers from Burgundy and 41.6 % by the winemakers from Jura. The main difference between the two groups was observed for the white wine oxidation free word association (14.8 % in Burgundy vs 6.5 % in Jura) and the premature oxidation definition task (22.7 % in Burgundy vs 13.8 % in Jura). The proportion of terms retained for the Chardonnay oxidation definition task was equivalent in the two groups (20.8 % in Burgundy vs 21.3 % in Jura). The concepts of oxidation in white wines and premature oxidation seem thus to be more evocative for winemakers from Burgundy than for winemakers from Jura.

Observation of the word clouds (Supplementary material) and CA performed on the frequency counts (Fig. 1) suggests that the concept of oxidation is not a unified concept. It is modulated both by the experience of the experts, and the context in which it is used. For the first task, the three most frequent terms in Burgundy were *bottle* (23), *problem* (22), and *aroma* (17) whereas, in Jura, they were *Jura* (23), *region* (14), and *vin jaune* (12). For the second task, the three most frequent terms in Burgundy were *fault* (15), *Burgundy* (14), and *bottle* (14) and in Jura Savagnin (21), *Jura* (20), and *fault* (20). Finally, winemakers from Burgundy associated premature oxidation with *bottle* (38), *problem* (24), and *oxygen* (17) and winemakers from Jura with *ageing* (21), *good* (13), and *sulphur* (12). The CA showed that the distances between the three sub-corpuses were greater in Jura than in Burgundy, indicating the representation of oxidation is less dependent on the context in which the term is used for the winemakers from Burgundy than for those of Jura.

### 3.2. Co-occurrence analysis of the corpuses

#### 3.2.1. Task 1: Oxidation in white wines

The similarity trees resulting from the co-occurrence analyses of the free association task are presented in Fig. 2. Both trees were organised around two poles: oxidation and wine. For the winemakers from





Burgundy (Fig. 2a), the oxidation pole was richer and more structured than the wine pole. Five structured dimensions were associated with the oxidation pole: the type of wines (*white, Burgundy wine, great wine*), premature oxidation (*premature, natural*), problem (*big problem, year, cork*), evolution (*maturation, temporality, oxidative*) and SO<sub>2</sub> (*sulphur dioxide dose*). No clear dimension emerged from the wine pole, which was associated with unrelated terms such as *bottle, structure, aroma, must, technique, transfer, oxygen* or *Chardonnay*.

On the contrary, for winemakers from Jura (Fig. 2b), the wine pole was more developed and structured than the oxidation pole. The wine pole was composed of two main dimensions: one linked to the Jura area and the other one describing flor wines, developed under a film of yeast. The oxidation pole was associated with only a few terms that were not linked together: *chemical, vin jaune, defect* and *apple*.

To sum up, as was already suggested by the word clouds, for Jura winemakers, oxidation is clearly related to a wine style namely vin jaune whereas for Burgundian winemakers it is more associated to oenological phenomena.

### 3.2.2. Task 2: Oxidation in Chardonnay wines

The similarity trees resulting from the co-occurrence analyses of the Chardonnay oxidation definition task are presented Fig. 3. Again, a similar structuration of the trees in three poles “Chardonnay”, “oxidation” and “wine” was obtained for the two groups of participants. For winemakers from Burgundy (Fig. 3a), the Chardonnay pole was less developed and structured than the oxidation and wine poles suggesting that the grape variety is not crucial in the definition of oxidation for these participants. The wine pole was associated with the term Burgundy showing that they think that oxidation is a topic strongly associated with their region. This pole was also associated with some winemaking parameters such as press, bottle, SO<sub>2</sub>, air, as well as evolution and its sensory impact on freshness and honey flavour. Finally, the oxidation pole was linked to wine faults in young wines, going up to

premature oxidation and their associated sensory characteristics: apple and walnut. A few participants mentioned the opposite phenomenon: reduction.

Unlike what was observed for the winemakers from Burgundy, the Chardonnay pole of the winemakers from Jura was richer and more structured than the two other poles (Fig. 3b). This pole is mainly associated to either the style of wine (flor wine) and grape variety (Savagnin, varietal from Jura) or to characteristic of Chardonnay wine (tradition, barrel, white). A few winemakers associated Chardonnay to *big problem*. The oxidation pole for the Jura winemakers showed simpler ramifications with some associations to *minerality* and *terroir* as well as the notion of *interesting bottle*. Again a few winemakers mentioned the idea of a problem linked to *ageing*. Finally, the wine pole was associated to sensory terms such as *acidity* and *apple aroma* as well as some technical aspects like *oxygen* and *vat* and origin terms like *jurassien*.

### 3.2.3. Task 3: Premature oxidation

The importance and connectivity of the trees obtained for the premature oxidation definition task were rather similar for the two groups of participants (Fig. 4), however, the content of the poles revealed some differences. For both groups the wine pole was more developed than the oxidation and premature poles.

For winemakers from Burgundy (Fig. 4a) the wine pole was mostly linked to bottle features, and temporality (*premoxy* and *evolution*). This pole was also associated with terms linked with wine production (*practice, producer, dissolved oxygen, reduction*) and wine aroma (*aroma, aromatic*). The oxidation pole was related to the idea of a problem as well as that of SO<sub>2</sub> management. Finally, the premature pole was associated with the issue of oxygen management during bottling, as well as the notion of cork and fault.

For winemakers from Jura (Fig. 4b), the wine pole was different from that observed for winemakers from Burgundy. It was associated with the idea of Burgundy terroir, flor wine and *sulphur dioxide*. The oxidation

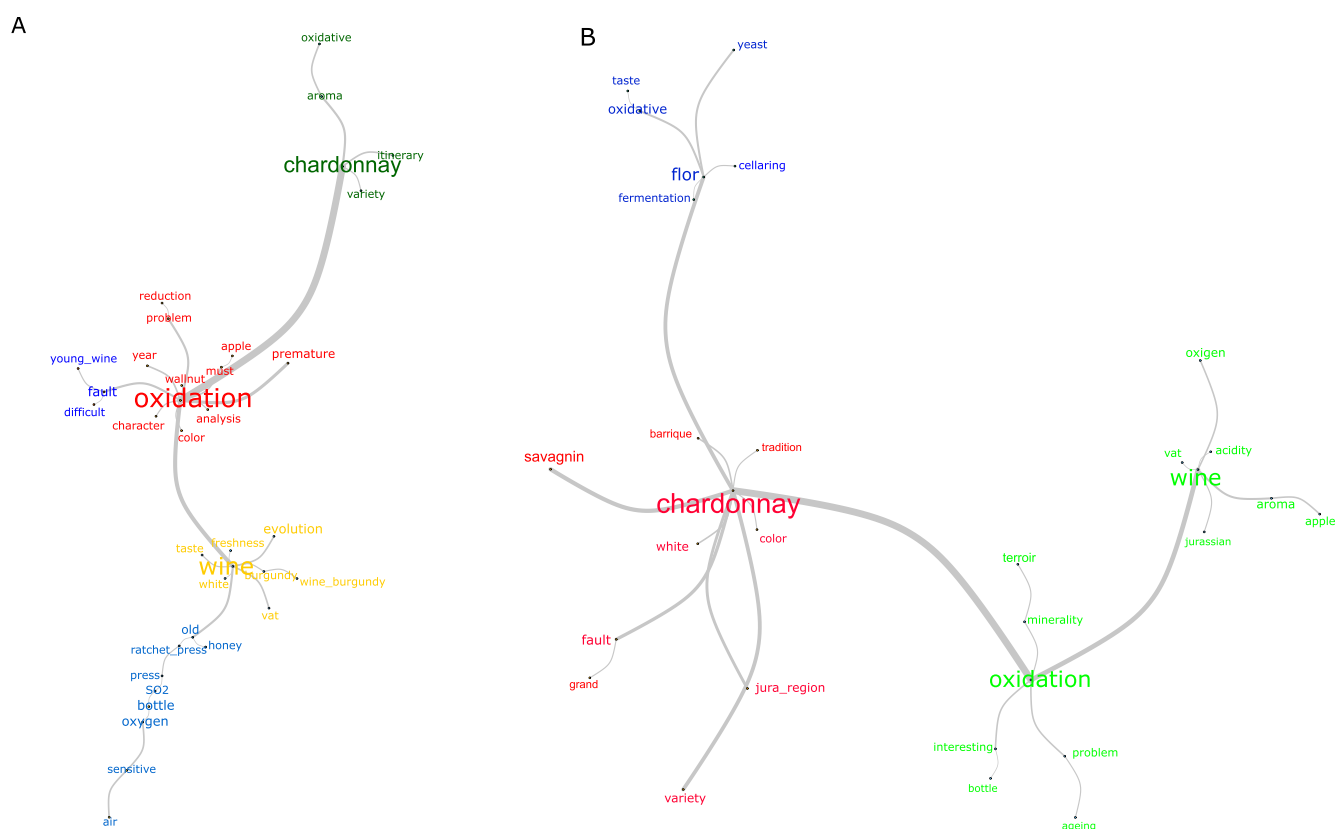


Fig. 3. Similarity trees obtained from the co-occurrence analysis of the a) Burgundy and b) Jura corpus for task 2 (Chardonnay oxidation definition task).

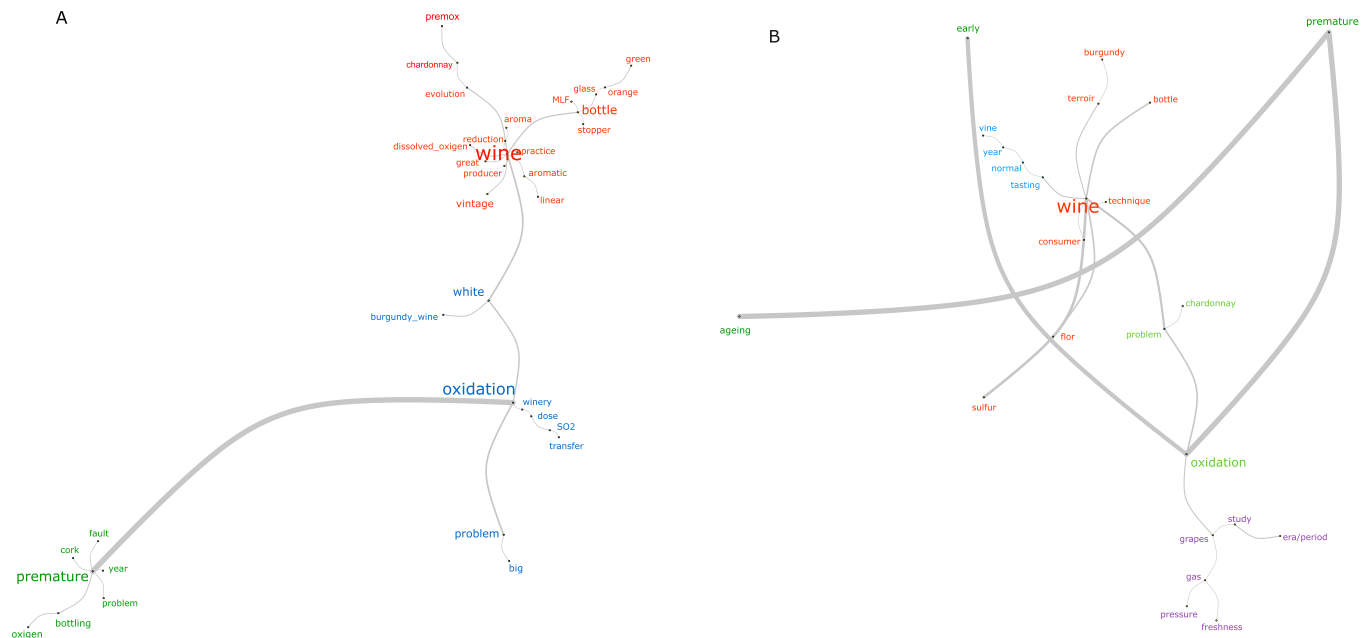


Fig. 4. Similarity trees obtained from the co-occurrence analysis of the a) Burgundy and b) Jura corpus for task 3 (premature oxidation definition task).

pole was associated with the notion of a problem like in Burgundy but a problem that is linked to Chardonnay wines as well as the notion of grape which was associated with ideas like *study* and *gas*. They also defined premature oxidation as being an early phenomenon that is linked to ageing. Globally, the more chaotic aspect of the similarity tree obtained for winemakers from Jura suggests a more diffuse representation of premature oxidation than that observed for Burgundy winemakers.

### 3.3. Thematic analysis

#### 3.3.1. Different types of oxidation in Burgundy and in Jura

As observed in the previous analyses, oxidation is more often perceived as a problem among winemakers from Burgundy than among winemakers from Jura. While more than half of the winemakers from Burgundy associated oxidation in white wine (task 1) to a “*problem*” or a “*defect*”, and even spoke about “*fear*” (B8), it was considered as a *defect* by only a third of the winemakers from Jura (J7, J11, J16, and J27). This notion of *defect* seemed more consensual for winemakers from Jura when they focused on oxidation in Chardonnay wines (task 2), since more than half of them cited this term. This idea is explained by J3 as follows: “*For me, oxidation on a Chardonnay is a real flaw in the wine (...) we realized that Savagnin wine could withstand oxidation, because it had the means to protect and control itself*”.

This perception of oxidation as a defect is modulated by a temporality dimension (see e.g. Fig. 2a). For winemakers from Burgundy, oxidation may be related to a natural phenomenon due to wine ageing and seemed to be more accepted than *premature oxidation*, cited both for white wines (task 1) and Chardonnay wines (task 2): “*if it’s a 50 year old bottle it is forgivable*” (B5), “*There is the good one that is normally done on the ageing of a wine*” (B8), “*a Chardonnay that has aged very well for 30 years which has small oxidative notes, a little hazelnut that can be just sumptuous*” (B17), “*it is natural in a very long term, it is part of the evolution*” (B21).

For winemakers from Jura, oxidation has a more positive connotation linked to the oxidative style of winemaking traditionally used in their region. In task 1, the wine pole was clearly associated with flor wines, a type of wine which develop a flor of yeast on the surface, through managed oxidation “*this is a process that we use but in a careful way with the use of a flor of yeast*” (J9) or “*a beautiful managed oxidation*

*which will be provided by yeasts*” (J24). Although flor wines were also mentioned by some winemakers from Burgundy in association with oxidation in Jura, as expressed by B17: “*an oxidation in wine with a flor, it can be fantastic*”, winemakers from Jura have a quite different conception of oxidation. For them, oxidation in white wines is a deliberate practice: “*there are oxidative maturation methods which are quite common in the Jura*” (J26). They considered this oxidation as “*biological*” (J4 and J11), offering a wine with “*complexity*” (J2, J11) and aromatic diversity, such as “*spicy notes*” (J2, J4), “*apple*” and “*walnut*” (J4, J24). The grape variety Chardonnay (task 2) was also associated with flor wines as illustrated by J24: “*in the Jura the oxidation of Chardonnay wines, when it is wanted and worked will give interesting things*” and J13 “*we worked on the oxidation on both Savagnin and Chardonnay*” (J13),

#### 3.3.2. Sensory dimensions associated with oxidation and premature oxidation

In all similarity trees, oxidation was associated with sensory descriptors. Winemakers from Burgundy used the same terms to describe oxidation independently of the context. These terms describe the visual aspects of the wines, in particular their colour: “*orange*” (B1, B17) or “*yellow*” (B20) or their loss of “*colour*” (B12) as well as their aromas: “*apple*” or “*bruised apple*” (B1, B6, B8, B19, and B21), “*honey*” (B1, B6, B15, and B17), “*nut*” (B10, B12, and B19), “*caramel*”, “*dried grape*” and “*beeswax*” (B1, B17), “*oxidised apricot*” (B6), or “*bruised pear*” and “*curry*” (B8). A “*loss of freshness*” (B6, B12) was also mentioned when they talked about oxidation in Chardonnay wines.

Compared with winemakers from Burgundy, winemakers from Jura generated less sensory terms. They tended to use shared descriptors, such as: “*apple*” (J4, J9, and J24), “*wax*” (J9) or “*honey*” (J7 and J9) as well as some idiosyncratic terms such as “*Heaviness and bitterness [...] a decrease of wine body*” (J2), “*maderised aromas*” (J3), “*a golden colour [...] bruised apple*” (J4) and “*ripe fruit*” (J7). Unlike what we observed for Burgundy, only one winemaker from Jura described the sensory profile of premature oxidation in wines as a loss of “*aromatic freshness*” (J4).

#### 3.3.3. Premature oxidation: A concept more salient in Burgundy than in Jura

For the tasks related to white wine oxidation (task 1) and Chardonnay oxidation (task 2), the term *premature* appeared only on the word clouds and the co-occurrence trees of the winemakers from

Burgundy. This term was spontaneously cited by eight winemakers from Burgundy and only one from Jura. This observation revealed the importance of the relationship between premature and oxidation in the mental representations of the winemakers from Burgundy. *Premature oxidation* was spontaneously described as an early and negative evolution of the wine as illustrated by participants B5: “*premature oxidation after a year or two years of bottles, it’s illogical*” and B8: “*premature oxidation, that is to say that even once after 6 months [...] the wine is on the decline*”. This phenomenon was strongly associated with the region and the wines of Burgundy: “*big problem in Burgundy wines*” (B8), “*some white Burgundy wines [...] were oxidised very very quickly*” (B15). For the premature oxidation definition task (task 3), some winemakers from Burgundy specified that “*all wineries have been affected, even the most prestigious*” (B1).

With one exception, winemakers from Jura did not mention spontaneously the term of premature oxidation. For task 3, almost a third of winemakers from Jura had not heard of this term before. Some of them used the expression *premature ageing* rather than *premature oxidation* (J4, J11, J23 and J26) as seen in the similarity tree (Fig. 3b). However, the winemakers from Jura who were aware of the concept of premature oxidation, associated premature oxidation to Burgundy wines and like Burgundy winemakers define it as an early evolution of the wines: “*deviations in young wines*” (J26) or “*after a year or even two years, it is still early oxidation*” (J9) which lead to defected wines, “*that seem tired*” (J11), or that “*do not hold after bottling*” (J27).

#### 4. Discussion

Our main goal was to compare how French winemakers from two different wine regions (Burgundy vs Jura) conceptualised the notion of oxidation in white wine. From a sensory point of view, oxidation is a rather ambiguous term as it can have both a positive and a negative connotation depending on the overall context. The same olfactory patterns might be subjectively interpreted as a fault or a quality, somewhat like in the case of bistable visual perception (the same image can be perceived as a young or an old lady). Previous experience might create expectations which influence the interpretation of ambiguous sensory patterns via different mental representations. In the case of wine, the same sensory information, for instance honey aromas, can be interpreted differently depending on the information given to the tasters (e.g. the vintage of the wine). Honey can be judged as faulty in a young wine whereas it is expected and considered as positive in an older wine.

In this work, we hypothesised that winemakers coming from two wine areas with different oenological practices regarding wine oxidation would attach different meanings to the concept of oxidation. More specifically we expected winemakers from Jura to have a more positive view of oxidation than winemakers from Burgundy. A simple frequency count of the terms associated with the prompt “white wine oxidation” showed that it was indeed the case. For winemakers from Burgundy, “oxidation” triggers the idea of a problem whereas it evokes the idea of wine making or wine style in Jura. Oxidation was globally perceived as a fault more often in Burgundy than in Jura. Winemakers from Burgundy had also a more complex representation of oxidation with a clear distinction between “oxidation”, which may be perceived as positive, and “premature oxidation” clearly perceived as negative. Even though premature oxidation has had a lot of visibility for Burgundy wines (Meadows and Barzelay, 2018), this phenomenon affects many wine regions in the world as evidenced by the large number of publications from different countries on the topic (see Oliveira et al, 2011 for a review). The notion of premature oxidation did not seem to be integrated in the representation of oxidation developed by winemakers from Jura.

These conceptual differences can be explained in terms of everyday practices and the goals associated with these practices. In terms of daily winemaking practices there are clear differences between the two regions in particular concerning the elaboration of flor wines. Moreover, the objectives in terms of wine style are also quite different, even

concerning Chardonnay wine, on one hand because Chardonnay from Jura (with some exceptions) are generally made in a fresh style meant to be drunk young and, in the other hand, because of the emergence of flor wines made from this grape variety in the Jura. Previous studies have interpreted the effect of practices on the development of wine representations by experts in terms of perceptual learning (Honoré-Chedozzeau et al., 2019; Parr, 2019). Perceptual learning can be defined as an increase in the ability to extract information from the environment because of practice and experience with stimuli coming from this environment (Gibson and Gibson, 1955). Thus, an essential feature of perceptual learning is to reflect the effect of experience and exposure to stimuli. The differences observed in our study in terms of mental representations between the two groups of wine experts could be explained by the fact that both groups did not pay quite the same attention to the phenomenon of oxidation due to the environment in which they work. This could be related to attentional weighting mechanisms (Goldstone, 1998) that developed with their familiarity with certain types of wine. According to Goldstone (1998) attentional weighting can be seen as an adaptation of perception for a task or an environment by an increase in attention for relevant perceptual dimensions and characteristics and/or a decrease in attention for irrelevant dimensions and characteristics. This interpretation is in line with a recent study by Otheguy et al. (2021) showing that different kinds of wine experts (wine producers, wine writers and wine sellers) had different mental representations of the Beaujolais Pierres Dorées category. The authors explained these differences in terms of training, professional practices and goals concerning these wines. The kind and amount of training have also been linked to odour sensitivity by Tempère et al. (2011). The authors explored the diversity of detection thresholds for key wine-related compounds using a large and diverse expert panel (oenologists, wine growers, wine merchants, wine brokers). The results showed a greater sensitivity to diacetyl and ethylphenols by the experts that had academic degrees on wine tasting over the rest of the experts.

Different kinds of expertise or different wine environments can result in different ways in assessing the potential negative impact of oxidation on wine quality. One important element that emerged from our results is the temporality or the moment in which the oxidative attributes start appearing. Although it is generally admitted that quality judgments are contextual rather than universal, in the case of wine oxidation it seems that contextual information is critical to properly judge the quality of the wines. Knowing the age of the wine or the goal of the producer seem necessary information to assess whether perceived sensory signals match the expected sensory characteristics. This raises the question of the use of blind tasting when judging, for instance, wines from different vintages. This is an important question to be investigated in future research.

#### 5. Limitations

A limitation of this study was that the task itself narrowed down participants’ responses to Burgundy Chardonnay and flor Savagnin from Jura, which limits the generalisability of our findings. However, for the first question, which was aimed to white wine oxidation in general (regardless varieties or regions), participants spontaneously narrowed their answers to these two types of wines, leaving aside other rising types of wines like Aligoté with oak ageing, or Savagnin without flor ageing highlighting the weight of these wines in their representations. Another limitation was the moderate size of the respondent groups for each region which prevents accessing a more diverse and nuanced conceptualizations of white wine oxidation.

#### 6. Conclusion

Our study has shown that oxidation, as a sensory concept, is much more ambiguous than what is suggested in oenology manuals. Wine tasters’ mental representations of oxidation are strongly modulated by



their experience and arguably, by the available information concerning the samples being tasted as vintage or expected wine style. An important aspect regarding the oxidation problem is to understand the potential causes in terms of winemaking process. This issue is out of the scope of this study and will be the subject of a further study.

### Ethical statement

In agreement with the 2013 Helsinki declaration, Participants were asked to read an information sheet and sign a consent form. It was mentioned that interviews would be audio recorded and that the tapes would be used only for academic research and guaranteed anonymity of participants.

### CRedit authorship contribution statement

**Jérôme Mallard:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation. **Dominique Valentin:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Jordi Ballester:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis.

### Funding

This work was supported by the Regional Council of Bourgogne-Franche-Comté / BPI France N° DOS0093585/00 and the “Fonds Européen de Développement Régional” (PO FEDER-FSE Bourgogne 2014/2020, N° SYNERGIE BG0018685).

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Acknowledgements

The authors would like to thank Véronique Boulanger for technical assistance, as well as the wine experts for their participation in the study.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodres.2024.115341>.

### Data availability

The authors do not have permission to share data.

### References

- Ballester, J., Abdi, H., Langlois, J., Peyron, D., & Valentin, D. (2009). The odor of colors: Can wine experts and novices distinguish the odors of white, red, and rosé wines? *Chemosensory Perception*, 2(4). <https://doi.org/10.1007/s12078-009-9058-0>
- Ballester, J., Patris, B., Symoneaux, R., & Valentin, D. (2008). Conceptual vs. perceptual wine spaces: Does expertise matter? *Food Quality and Preference*, 19(3). <https://doi.org/10.1016/j.foodqual.2007.08.001>
- Culleré, L., Cacho, J., & Ferreira, V. (2007). An assessment of the role played by some oxidation-related aldehydes in wine aroma. *Journal of Agricultural and Food Chemistry*, 55(3), 876–881. <https://doi.org/10.1021/jf062432k>
- David-Vaizant, V., & Alexandre, H. (2018). Flor yeast diversity and dynamics in biologically aged wines. *Frontiers in Microbiology*, 9, 2235. <https://doi.org/10.3389/fmicb.2018.02235>
- Escudero, A., Hernández-Orte, P., Cacho, J., & Ferreira, V. (2000). Clues about the role of methional as character impact odorant of some oxidized wines. *Journal of Agricultural and Food Chemistry*, 48(9), 4268–4272. <https://doi.org/10.1021/jf991177j>
- Escudero, A., Asensio, E., Cacho, J., & Ferreira, V. (2002). Sensory and chemical changes of young white wines stored under oxygen. An assessment of the role played by aldehydes and some other important odorants. *Food Chemistry*, 77(3), 325–331. [https://doi.org/10.1016/S0308-8146\(01\)00355-7](https://doi.org/10.1016/S0308-8146(01)00355-7)
- Franco-Luesma, E., Honoré-Chedozeau, C., Ballester, J., & Valentin, D. (2019). Oxidation in wine: Does expertise influence the perception? *LWT*, 116. <https://doi.org/10.1016/j.lwt.2019.108511>
- Gabrielli, M., Fracassetti, D., Romanini, E., Colangelo, D., Tirelli, A., & Lambri, M. (2021). Oxygen-induced faults in bottled white wine: A review of technological and chemical characteristics. *Food Chemistry*, 348, Article 128922. <https://doi.org/10.1016/j.foodchem.2020.128922>
- Gibson, J., & Gibson, E. (1955). Perceptual learning; differentiation or enrichment? *Psychological Review*. <https://doi.org/10.1037/h0048826>
- Goldstone, R. L. (1998). Perceptual Learning. *Annual Review of Psychology*, 49(1), 585–612. <https://doi.org/10.1146/annurev.psych.49.1.585>
- Grainger, K. (2021). In *Wine Faults and Flaws: A Practical Guide*. John Wiley & Sons. <https://doi.org/10.1002/9781118979082>
- Green, J. A., Parr, W. V., Breitmeyer, J., Valentin, D., & Sherlock, R. (2011). Sensory and chemical characterisation of Sauvignon blanc wine: Influence of source of origin. *Food Research International*, 44(9). <https://doi.org/10.1016/j.foodres.2011.06.005>
- Honoré-Chedozeau, C., Lelièvre-Desmas, M., Ballester, J., Chollet, S., & Valentin, D. (2017). Knowledge representation among assessors through free hierarchical sorting and a semi-directed interview: Exploring Beaujolais wines. *Food Quality and Preference*, 57. <https://doi.org/10.1016/j.foodqual.2016.11.008>
- Honoré-Chedozeau, C., Desmas, M., Ballester, J., Parr, W. V., & Chollet, S. (2019). Representation of wine and beer: Influence of expertise. *Current Opinion in Food Science*, 27, 104–114. <https://doi.org/10.1016/j.cofs.2019.07.002>
- Kamada, T., & Kawai, S. (1989). An algorithm for drawing general undirected graphs. *Information Processing Letters*, 31(1), 7–15. [https://doi.org/10.1016/0020-0190\(89\)90102-6](https://doi.org/10.1016/0020-0190(89)90102-6)
- Karbowiak, T., Gougeon, R. D., Alinc, J. B., Brachais, L., Debeaufort, F., Voilley, A., & Chassagne, D. (2009). Wine oxidation and the role of cork. *Critical Reviews in Food Science and Nutrition*, 50(1), 20–52. <https://doi.org/10.1080/10408390802248585>
- Liberatore, M. T., Pati, S., Del Nobile, M. A., & La Notte, E. (2010). Aroma quality improvement of Chardonnay white wine by fermentation and ageing in barrique on lees. *Food Research International*, 43(4), 996–1002. <https://doi.org/10.1016/j.foodres.2010.01.007>
- Martin, B., Etievant, P. X., Le Quere, J. L., & Schlich, P. (1992). More clues about sensory impact of sotolon in some flor sherry wines. *Journal of Agricultural and Food Chemistry*, 40(3), 475–478. <https://doi.org/10.1021/jf00015a023>
- Meadows, A. D., & Barzelay, D. E. (2018). *Burgundy Vintages: A History from 1845*. BurghoundBooks.com.
- Milheiro, J., Cosme, F., Filipe-Ribeiro, L., & Nunes, F. M. (2020). *Port Wine: Production and Ageing*. In F. Cosme, L. Filipe-Ribeiro, & F. M. Nunes (Eds.), *Chemistry and Biochemistry of Winemaking*. IntechOpen: Wine Stabilization and Ageing.
- Oliveira, C. M., Ferreira, A. C. S., De Freitas, V., & Silva, A. M. S. (2011). Oxidation mechanisms occurring in wines. *Food Research International*, 44(5), 1115–1126. <https://doi.org/10.1016/j.foodres.2011.03.050>
- Otheguy, M., Honoré-Chedozeau, C., & Valentin, D. (2021). Do wine experts share the same mental representation? A drawing elicitation study with wine makers, sellers, and critics. *Food Quality and Preference*, 94, Article 104302. <https://doi.org/10.1016/j.foodqual.2021.104302>
- Parr, W. (2007). *Application of Cognitive Psychology to Advance understanding of Wine Expertise*. In K. H. Kiefer (Ed.), *Applied Psychology Research Trends*. Nova Science Publishers Inc.
- Parr, W. V. (2019). Demystifying wine tasting: Cognitive psychology's contribution. *Food Research International*, 124, 230–233. <https://doi.org/10.1016/j.foodres.2018.03.050>
- Ratinaud, P. (2009). IRaMuTeQ: Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires. Available at: <http://www.iramuteq.org>.
- Romanet, R. (2019). *Contribution à l'étude moléculaire de la stabilité oxydative des vins blancs de Bourgogne*. Université Bourgogne Franche-Comté. PhD thesis.
- Sáenz-Navajas, M. P., Arias-Pérez, I., Ferrero-Del-Teso, S., Escudero, A., Ferreira, V., Fernández-Zurbano, P., & Valentin, D. (2021). Access to wine experts' long-term memory to decipher an ill-defined sensory concept: The case of green red wine. *OENO One*, 55(1), 69–79. <https://doi.org/10.20870/oeno-one.2021.55.1.4475>
- Silva Ferreira, A. C., de Pinho, P. G., Rodrigues, P., & Hogg, T. (2002). Kinetics of oxidative degradation of white wines and how they are affected by selected technological parameters. *Journal of Agricultural and Food Chemistry*, 50(21), 5919–5924. <https://doi.org/10.1021/jf0115847>
- Silva Ferreira, A. C., Hogg, T., & Guedes de Pinho, P. (2003). Identification of key odorants related to the typical aroma of oxidation-spoiled white wines. *Journal of Agricultural and Food Chemistry*, 51(5), 1377–1381. <https://doi.org/10.1021/jf025847o>
- Tempère, S., Cuzange, E., Malak, J., Bougeant, J. C., De Revel, G., & Sicard, G. (2011). The training level of experts influences their detection thresholds for key wine compounds. *Chemosensory Perception*, 4(3), 99–115. <https://doi.org/10.1007/s12078-011-9090-8>
- Ugliano, M. (2013). Oxygen contribution to wine aroma evolution during bottle aging. *Journal of agricultural and food chemistry*, 61(26), 6125–6136. <https://doi.org/10.1021/jf400810v>